SAFETY ASSESSMENT MODEL OF COASTAL PASSENGER VESSEL IN THE PERSPECTIVE OF LIFE JACKET COMPATIBILITY

AHMAD FAIZAL BIN AHMAD FUAD

UNIVERSITI TEKNOLOGI MALAYSIA

SAFETY ASSESSMENT MODEL OF COASTAL PASSENGER VESSEL IN THE PERSPECTIVE OF LIFE JACKET COMPATIBILITY

AHMAD FAIZAL BIN AHMAD FUAD

A thesis submitted in the fulfilment of the
requirements for the award of the degree of
Doctor of Philosophy (Mechanical Engineering)

Faculty of Mechanical Engineering
Universiti Teknologi Malaysia

DECEMBER 2015

To my beloved family, teachers and supporting group in UTM

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to my supervisors, Prof. Ir. Dr. Ab. Saman bin Abd. Kader and Associate Prof. Dr. Mohd Zamani bin Ahmad for their kind guidance and professional support and sharing of experience during the execution of this research. The research would not be completed and successful without their contributions and perseverance.

Last but least, I would like to thank my beloved parents Dato' Brig. Jen. Ahmad Fuad Harun and Che Ton Abd Rahman, parent in-laws, my wife Nor Azazura, my dear sisters Abidah and Salamah, and other family members that supported me throughout this PhD journey.

I would like to express my appreciation to former Dean of Faculty of Marine Science and Maritime Studies UMT, Dato' Prof. Saharuddin for his approval and encouragement in my PhD study by using the SLAI scholarship from MOHE. I would like also to thank Capt. Mohd Naim, Capt. Noor Apandi, Mohd Hafizi, Izhar, Mat Nasir, and Hafiz of Department of Nautical Studies and Maritime Transportation UMT for their continuous support.

I would like to thanks my friends in UTM that supported me during my study; namely Azuwan, Aminuddin, Azmirul, Aswin, Fauzi, Razak, Dr. Nurzaher, Nurol, Sunarsih, Zulkifli, Asmawi, Nurhanani, Raihan, Narisa, Zamari. Khudzairi and other names not mentioned.

ABSTRACT

This research was conducted due to frequent occurrence of passenger vessel accidents related to the use of life jackets, which believed due to incompatibility between life jackets and passenger vessels. To address this problem, the research sets to develop a safety assessment model of coastal passenger vessel (CPV) in the perspective of life jacket's compatibility, which is known as Life Jacket Compatibility Index (LCI) model. The main purpose of LCI model is to evaluate the life jacket's compatibility with CPV. The LCI model was developed based on a combination of variables from four previous safety models. Compatibility was introduced as a new variable in the present model. The development of the LCI model started by mapping the variables from both life jacket model and passenger vessel safety combined model. Variables were selected based on the research criteria and used to develop the Life Jacket Compatibility Index (LCI) model. The LCI model was transformed into LCI Static and LCI Dynamic algorithms that are based on Fault Tree analysis approach. The LCI Static assesses the life jacket's compatibility with CPV which is under the approved plan and number of passengers, while the LCI Dynamic assesses the same compatibility during CPV is in the operational mode. The LCI model's accuracy was verified by using regression method and the results were further validated by case studies and sensitivity analyses. Results from LCI Static showed that the open-deck CPV *Explorer 320* equipped with inherently buoyant life jackets has better compatibility (2.79) than closed-deck CPV *Duta Pangkor 3* and *Bahagia No. 1* (1.79 and 1.84 respectively). The LCI model was used to improve the safety performance of *Bahagia No. 1*. It was found that LCI Dynamic of the vessel can be improved by 3.4% when the number of passengers was reduced from 57 to 55. In conclusion, the newly developed LCI model is significant to assess and improve the safety of CPV.

ABSTRAK

Kajian ini dijalankan kerana berlakunya kejadian kemalangan kapal penumpang yang kerap berkaitan dengan penggunaan jaket keselamatan, yang dipercayai disebabkan oleh ketidakserasian antara jaket keselamatan dan kapal penumpang. Bagi menangani masalah ini, kajian ini telah membangunkan model penilaian keselamatan kapal penumpang pesisir (CPV) dalam perspektif keserasian dengan jaket keselamatan yang dikenali sebagai model Indeks Keserasian Jaket Keselamatan (LCI). Tujuan utama model LCI dibangunkan adalah untuk menilai keserasian antara jaket keselamatan dengan CPV. Model LCI telah dibangunkan berdasarkan gabungan pembolehubah-pembolehubah dari empat model keselamatan sebelumnya. Keserasian diperkenalkan sebagai pembolehubah baru dalam model ini. Pembangunan model LCI bermula dengan pemetaan pembolehubah dari kedua-dua model jaket keselamatan dan model keselamatan kapal penumpang yang gabungkan. Pembolehubah-pembolehubah dipilih berdasarkan kriteria penyelidikan dan digunakan untuk membangunkan model (LCI). Model LCI berubah menjadi algoritma LCI Statik dan LCI Dinamik dengan menggunakan pendekatan analisa *Fault Tree*. Fungsi LCI Statik adalah menilai keserasian jaket keselamatan dengan CPV berdasarkan pelan kapal dan bilangan penumpang yang diluluskan, manakala fungsi LCI Dinamik adalah menilai keserasian yang sama semasa CPV beroperasi. Ketepatan model LCI telah disahkan dengan menggunakan kaedah regresi dan pengesahan lanjut telah buat melalui kajian kes dan analisis sensitiviti. Keputusan LCI Statik menunjukkan bahawa CPV jenis dek terbuka *Explorer 320* yang dilengkapi dengan jaket keselamatan apung kekal mempunyai keserasian yang lebih baik (2.79) berbanding CPV jenis tertutup dek *Duta Pangkor 3* dan *Bahagia No. 1* (1.79 dan 1.84 masing-masing). Model LCI telah digunakan untuk meningkatkan prestasi keselamatan *Bahagia No. 1*. Adalah didapati bahawa LCI Dinamik kapal tersebut boleh dipertingkatkan sebanyak 3.4% apabila bilangan penumpang dikurangkan daripada 57 kepada 55. Kesimpulannya, model LCI yang baru dibangunkan ini adalah penting untuk menilai dan meningkatkan keselamatan CPV.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

BSS	-	Boating Safety Scale
C	-	Comply
CATI	-	Computer Assisted Telephone Interviewing System
CLIA	-	Cruise Lines International Association, Inc.
FAA	-	Federal Administration of Aviation
FSA	-	Formal Safety Assessment
GA	-	General Arrangement
HELP		Heat Escape Lessening Position
IMO	-	International Maritime Organization.
ISO	-	International Organization for Standardization
LCI	-	Life Jacket Compatibility Index
LOA	-	Length Overall
LSA	-	International Life Saving Appliances Code
LSI	-	Life Saving Index
LWL	-	Waterline Length
MAIB	-	Marine Accident Investigation Branch
MCA	-	Marine and Coast Guard Agency UK
MSC	-	Maritime Safety Committee
MV	-	Motor Vessel
NC		Not Comply
NTSB	-	National Transport Safety Board
PFD	-	Personal Floatation Device
RBCM	-	Risk Based Compliance Assessment Model
RRN	-	Risk Ranking Number
SOLAS	-	International Convention on the Safety of Life at Sea 1974
SEE	-	Standard Error of Estimate
SPSS	-	Statistical Package for Social Science

TMI	-	Turning Moment Index
TSB	-	Transportation Safety Board of Canada
UK	-	United Kingdom
USA	-	United States of America
USCG	-	United States Coast Guard

LIST OF SYMBOLS

CO_2	-	Carbon Dioxide
I_E	-	Physical Effectiveness; the probability the PFD maintains the wearer in a position which permits continuous breathing.
I_R	-	Reliability; the probability that the PFD performs as designed.
I_W	-	Wearability; the probability that PFD is worn by the victim when he enters the water in a marine accident.
I_W	-	The probability that PFD is worn immediately prior to entering the water in an accident.
I_{AC}	-	The probability that the PFD is accessible to a boater but not worn initially upon entering the water in an accident (accessibility index)
P_D	-	The probability that the accident victim dons the PFD in the water
P_H	-	The probability that the accident victim holds or lies upon the PFD in the water
E_W	-	The probability that the PFD maintains or turns the wearer in the water to a position with a minimum required freeboard to the lower respiratory passage within a specified time limit (effectiveness when worn)
E_H	-	The probability that the PFD provides minimum required freeboard to the lower respiratory passage for a relaxed person holding or lying upon the device in the water (effectiveness when held)
R	-	The probability that a PFD will operate successfully for a specified period of time and under specified conditions when used in the manner and for the purpose intended (reliability).
I_{AC}	-	Index of Accessibility
$F_{A_{MAX}}$	-	the greatest possible unadjusted accessibility factor score = 3.41
$F_{A_{MIN}}$	-	the smallest possible unadjusted accessibility factor score = -6.51

F_{AO}	-	the adjusted accessibility factor score taken as the zero point for I_{AC}
$NV5$	-	Proportion of Time Candidate PFD was Kept Accessible or Worn
$V70$	-	PFD worn by you + worn by another person (hour)
$V71$	-	PFD kept in open place (hour)
$V73$	-	Duration of outing (hour)
E_{W_B}	-	The probability that the PFD turns the unconscious/relax wearer to a position with adequate freeboard.
E_F	-	The proportion of dummies tested representing females on which the PFD performed satisfactorily.
P_F	-	The proportion of the recreational boating accident population which is female. E_M and P_M are defined comparably for males.
I_A	-	Accessibility Compatibility Index
I_{S_I}	-	Safety Instruction Compatibility Index
I_{S_C}	-	Space Compatibility Index
I_{AC}	-	Accessibility Compatibility Index
T_{AC}	-	Duration of LJ kept accessible (hour)
T_D	-	Duration of LJ donned by passenger (hour)
T_J	-	Duration of journey (hour)
$t_{a_{c_e}}$	-	time of life jacket end accessible
$t_{a_{c_s}}$	-	time of life jacket start accessible
t_{d_e}	-	time of life jackets taken off by passengers
t_{d_s}	-	time life jackets don by passengers
t_{j_e}	-	time of journey end
t_{j_s}	-	time of journey start
I_{S_I}	-	Safety Instruction Compatibility Index
S_{B_o}	-	Safety Briefing Observed
S_{B_r}	-	Safety Briefing Required
S_{B_o}	-	Safety Briefing Observed
I_{A_o}	-	Information on Emergency Alarm/Notification Observed
I_{X_o}	-	Information on Location of Emergency Exit Observed
$I_{J_{L_o}}$	-	Information on Location of Life Jacket Observed

$I_{J_{D_o}}$	-	Information on Life Jacket Donning Demonstration/Instruction Observed
I_{E_o}	-	Information on Location of Assembly Area or Embarkation Area Observed
I_{P_o}	-	Information on Location of Safety Placards/ Instructional Poster por Life Jacket Observed
$I_{J_{W_o}}$	-	Information on When To Don Life Jacket Observed
A_i	-	Availability of each element
F_l	-	Effectiveness of each element
s_j	-	score of effectiveness of each element observed
w_k	-	weightage of each element
F_l"	-	denotes F_l in fuzzy form.
S_{B_r}	-	Safety Briefing required
I_{A_r}	-	Information on emergency alarm/notification required
I_{X_r}	-	Information on location of emergency exit required
$I_{J_{L_r}}$	-	Information on location of life jacket required
$I_{J_{D_r}}$	-	Information on life jacket donning demonstration/instruction required
I_{E_r}	-	Information on location of assembly area or embarkation area required
I_{P_r}	-	Information on location of safety placards/ instructional poster for life jacket required
$I_{J_{W_r}}$	-	Information on when to don life jackets required
I_{SC_S}	-	Space Compatibility Index Static
S_A	-	Space available to don
S_{D_S}	-	Space required to don static
A_s	-	Area for each space
C_s	-	Possibility to don life jackets according to compatibility between type of space and type of life jacket
$J_{b_{fe}}$	-	Inherently buoyant type life jacket not compatible to don in fully enclosed space
$J_{b_{pe}}$	-	Inherently buoyant type life jacket not compatible to don in semi-

		enclosed space
J_{b_o}	-	Inherently buoyant type life jacket compatible to don in open space
$J_{i_{fe}}$	-	Inflatable type life jacket compatible to don in an enclosed space
$J_{i_{pe}}$	-	Inflatable type life jacket compatible to don in semi-enclosed space
J_{i_o}	-	Inflatable type life jacket compatible to don in open space
$J_{c_{fe}}$	-	Combination of Inflatable and Inherently Buoyant life jacket in fully enclosed space
$J_{c_{pe}}$	-	Combination of Inflatable and Inherently Buoyant life jacket in partially enclosed space
J_{c_o}	-	Combination of Inflatable and Inherently Buoyant life jacket in open space
N_i	-	Number of inflatable life jacket
N_b	-	Number of inherently buoyant life jacket
H_2	-	The inherently buoyant life jacket is not compatible with fully enclosed space of coastal passenger vessel
H_3	-	The inherently buoyant life jacket is compatible with open space of coastal passenger vessel
H_4	-	Inflatable life jacket is compatible with fully enclosed space of coastal passenger vessel
H_5	-	Inflatable life jacket is compatible with open space of coastal passenger vessel
H_6	-	The inherently buoyant life jacket is not compatible with partially-enclosed space of coastal passenger vessel
H_7	-	Inflatable life jacket is compatible with partially-enclosed space of coastal passenger vessel
S_{D_S}	-	Space required to don static
A_D	-	Area required to don one life jacket
N_P	-	Approved maximum number of passengers
LCI_D	-	Life jacket Compatibility Index Dynamic
I_{AC}	-	Accessibility Index
I_{SI}	-	Safety Instruction Index
I_{SCD}	-	Space Compatibility Index Dynamic
I_{SCD}	-	Space Compatibility Index Dynamic

S_A	-	Space available to don
S_{D_D}	-	Space required to don dynamic
S_{D_D}	-	Space required to don dynamic
A_d	-	Area required to don one life jacket
Np_i	-	Number of passenger dynamic

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter highlights the necessity of research on the development of the safety assessment model of coastal passenger vessel in the perspective of compatibility of life jackets with coastal passenger vessels. The problem statement and the research objective have been stated. The scope of the study and the significance of the research have also been itemized to show the research boundary and its strength and contribution respectively.

1.2 Background of Study

The safety of passenger vessels has been addressed by the establishment of the relevant national and international regulations since the aftermath of the RMS Titanic accident in 1912. One of the most important international safety regulations is the International Convention on the Safety of Life at Sea (SOLAS), 1974. Through the convention, continuous improvement on safety is introduced to passenger vessels in the aspect of design of passenger vessels, life-saving appliances, carriage of safety equipment and safety management system (IMO, 2009b).

Besides the introduction of safety regulations to improve the safety of passenger vessels, another way to improve the safety of passenger vessels is through the application of the assessment models. The examples of such models are Formal Safety Assessment for Cruise Ship introduced by Lois, *et al.* (2004), Boating Safety Scale introduced by Virk and Pikora (2011) and Crucial Safety Assessment Criteria for Passenger Ferry Services introduced by Lu and Tseng (2012).

One of the important safety aspects of passenger vessels is the carriage of life-saving appliances that contribute directly to the safety of passengers. The examples of the personal life-saving appliances are life jackets, life buoys, and immersion suits. Among the aforementioned, life jackets is the most important and carried for every person on board. The research on standards of life jackets has been initiated since 1950s until the present day (Ayub and Nejaim, 2003; Doll *et al.*, 1978b; Funkhouser and Fairlie, 1991; Gabb *et al.*, 1965; Hart, 1988; Herrmann, 1989; Lockhart *et al.*, 2005; Macdonald *et al.*, 2011; Macesker and Gareau, 1997; Macesker and White, 1992; Macintosh and Pask, 1957; Pask and Christie, 1962; Pask, 1961). The current enforced international standards for life jacket are International Life Saving Appliance Code under SOLAS 1974 and International Standard ISO 12402 (IMO, 1998, 2005, 2010; ISO, 2005). Similar with the passenger vessels, the improvement on safety of life jackets is through the introduction on assessment models. Examples of such research are Life-Saving Index model by Doll *et al.* (1978a, 1978b, 1978c) and Risk-Based Compliance Assessment Model by Ayub and Nejaim (2003).

Despite the continuous improvement on standards and the introduction of assessment models of passenger vessels and life jackets, accidents associated with the use of life jackets on board passenger vessels persist, although the number of cases is not significant. The examples of the two accidents highlighted in the following paragraph described the use of the inherently buoyant life jackets (fixed foam life jackets) in the enclosed space.

The first accident occurred in the year 1991 in Portsmouth, UK that caused loss of life of a nine year old female pupil that was wearing an inherently buoyant life jacket (MAIB, 2001). Upon capsizes, the pupil seated in the middle of the boat was trapped under the up-turned boat. Her escape impeded by the buoyancy force of life jacket that pushed her towards the surface. Her chances of survival would be higher if she trapped in an air pocket under the up-turned boat. Her situation worsened by the further submerged of the up-turned boat due to the weight of some of the pupils that sat on top of the boat and some clung to the side.

The second accident occurred in 2007 in Scotland, UK that had caused loss of life of a 15-year-old female cadet who was using an inflatable life jacket (MAIB, 2008). Initially upon capsized, four cadets was under the up-turned boat. Three cadets who were not inflating their life jacket managed to swim-out. However, the fourth cadet who inflated her inflatable life jacket was unable to swim-out from the up-turned boat due to the buoyancy force of her life jacket that forced her towards the surface. Her chances of survival would be higher like the three cadets who survived, if she did not inflate her life jacket.

1.3 Problem Statement

This study considered the examples of accidents stated in section 1.2 caused by compatibility issue between the life jackets and passenger vessels (Groff and Ghadiali, 2003). Furthermore, Doll *et al.* (1978) and Groff and Ghadiali (2003) suggested life jackets should be compatible with the user activity. With respect to the records of accidents and suggestion, the existing assessment models of passenger vessel do not address the issue of safety with respect to compatibility of life jackets with passenger vessels (Lois *et al.*, 2004; Lu and Tseng, 2012; Virk and Pikora, 2011). Instead, the existing models only emphasize on the availability and carriage of life jackets without looking into the aspect of suitability and support for life jackets to don and operate by passengers on board the passenger vessels.

1.4 Objective

With respect to the accidents associated with the usage of life jackets, this study would address the issue by developing a safety assessment model for the coastal passenger vessels in the perspective of compatibility of life jackets with the coastal passenger vessels as the main research objective. The development of the new model is based on a combination of the assessment models of life jackets with assessment models of the passenger vessels. The new model would be able to rate the compatibility of life jackets with coastal passenger.

The goal can be achieved by meeting the following objectives:

i. To develop a conceptual model to assess the compatibility of life jacket with passenger vessel by using variables in the previous models of life jackets and passenger vessels.
ii. To develop algorithm to assess compatibility of life jacket with coastal passenger vessel.
iii. To determine the algorithm is accurate and robust for application.

1.5 Scope of Study

The research limits its scope in the respective areas:

i. Coastal passenger vessels involved in single or multiple leg voyages in the coastal area (within 12nm or 21.6km from the nearest coast) and not equipped with cabin facility for passengers to stay overnight and must comply with the national regulations.
ii. Types of life jackets used this study are inherently buoyant (solid foam) and inflatable type, which comply with the national or international standard and available on board CPV in the required quantity.
iii. Survey to verify the new variable is carried out among Marine Officers of Marine Department Malaysia, which is the leading regulatory body in Malaysia with respect to maritime safety and shipping in Malaysia.

iv. The current model is developed based on a combination of variables from existing models of life jacket and models of passenger vessel which combines by compatibility as the new variable.

v. The variables selected to develop the new model should be able to produce result by on site evaluation without the additional requirement to conduct laboratory tests.

vi. The algorithm for the current model is developed by Fault Tree Analysis and Boolean Logic gate.

vii. Validation of the current functional test and one-at-a-time sensitivity analysis.

1.6 Significance of Study

The significances of this research are as follows:

Contribution to the knowledge of the new model is the assessment of coastal passenger vessel in a new perspective and would complement the existing assessment models.

The new model would serve as an enforcement tool for maritime authority to regulate the safety operation of the commercial coastal passenger vessels.

The new model would serve as a tool for plan approval of coastal passenger vessel for maritime authority, which determines the maximum capacity of passengers in a new way or perspective.

The new model is a new contribution to the field of maritime safety.

The new model would improve the safety of lives at sea.

1.7 Theoretical Framework

The development of the new model is based on the combination of two types of safety assessment models, namely safety assessment model for life jackets and assessment model for passenger vessels, and using compatibility variable to combine these two types of models. The assessment models for life jackets are Life Saving Index (LSI) model developed by Doll *et al.* (1978b) and Risk-Based Compliance for Personal Floatation Device (Risk-Comp PFDs) developed by Ayub and Nejaim (2003). While the assessment models for the passenger vessels are Formal Safety Assessment (FSA) for Cruise Ship developed by Lois *et al.* (2004), Crucial Safety Assessment Criteria for Passenger Ferry Services by Lu and Tseng (2012) and Boating Safety Scale by Virk and Pikora (2011). The combination of the two types of the model is to develop a new model to assess the safety of coastal passenger vessels, in the perspective of compatibility of life jackets to access, don and operation in the coastal passenger vessel.

1.8 The Organisation of the Thesis

This thesis is divided into six chapters, namely Introduction as Chapter 1, Literature Review as Chapter 2, Research Methodology as Chapter 3, Results as Chapter 4, Discussion as Chapter 5 and Conclusion as chapter 6. This is followed by References and Appendices.

This thesis divided of six main chapters where each chapter will focus on the topics as follows:

Chapter 1 is an introduction to the research where it describes briefly the background of the research, the problem statement, the research objective and the significance of the research.

Chapter 2 of the report contains a literature review for the purpose of understanding the topic of the research in detail. This chapter contains related literature on life jackets, passenger vessels, safety assessment models of life jackets, safety assessment models of passenger vessels, compatibility, accidents associated with life jackets and fuzzy.

Chapter 3 describes the methodology adopted for the research such the mapping of variables, statistics, Fault Tree analysis, Boolean logic gate, Triangular Fuzzy Number, and One-At-a-Time Sensitivity Analysis.

Chapter 4 shows the results of the research, namely model of Life Jacket Compatibility Index Static, Life Jacket Compatibility Index Dynamic, algorithm of Life Jacket Compatibility Index Static, algorithm of Life Jacket Compatibility Index Dynamic, results of verification and results of validation.

Chapter 5 discusses the results of chapter 4 in detail. The discussions focused on the achievement of the research objectives, the comparison of the current model with the existing models and the contribution of the current model in the field of maritime safety.

Chapter 6, which is the final chapter, presents the overall conclusion and recommendations for future research. This chapter highlights the findings and the contribution of the current research.

1.9 Summary

This chapter serves an introduction to this research, which mainly explains the background of the research, the problem statement, objectives of the research, scope of study, theoretical framework, and organisation of the whole thesis.

REFERENCES

Ahmad Fuad, A. F., Abd Kader, A. S., & Ahmad, M. Z. (2012). The Study to Determine the Compliance of Lifejacket used by Passenger Vessels in Malaysia with Life Saving Appliances Code. In *International Conference on Marine Technology*. Kuala Terengganu: Universiti Malaysia Terengganu.

Air Asia. (2009). *Safety Information*. Kuala Lumpur: Air Asia.

Ayub, B. M., & Nejaim, K. (2003). Risk-Based Compliance Assessment Models for Personal Flotation Devices. In *Fourth International Symposium on Uncertainty Modelling and Analysis* (pp. 55 – 60).

Baird, N. (1999, December). “Xunlong 2” Sea Lord 38 delivered to China. *Work Boat World*, 34.

Bala, I., Sharma, S. K., & Kumar, S. (2013). Exploring Raw Safety Aspects in Aviation Industry. *Computer Engineering and Intelligent Systems*, *4*(1), 80–97.

Beecham, B. (1999a, January). Patricia Olivia II. *Work Boat World*, 40–41.

Beecham, B. (1999b, October). Reef Rocket. *Work Boat World*, 31.

Beecham, B. (1999c, October). Suzanne. *Work Boat World*, 51.

Beecham, B. (2010, July). “Kurrowera I” Third of four, second generation Eco-Jet ferries by Aluminium Boats. *Work Boat World*, 33.

Brown, M. (1995, December). Andromeda. *Work Boat World*, 20.

Brown, M. (1999, July). “Draiocht Na Farraige” WaveMaster ferry for Ireland. *Work Boat World*, 19.

Burghardt, M. D. (1999). *Intoduction to Engineering Design and Problem Solving* (Internatio.). Singapore: McGraw-Hill.

Casio Computer Co. Ltd. (2000). *Casio Module No. 2273*. Tokyo: Casio Computer Co. Ltd.

Chang, Y.-H., & Liao, M.-Y. (2009). The effect of aviation safety education on passenger cabin safety awareness. *Safety Science*, *47*(10), 1337–1345.

Chang, Y.-H., & Yang, H.-H. (2011). Cabin safety and emergency evacuation: passenger experience of flight CI-120 accident. *Accident Analysis and*

Prevention, *43*(3), 1049–55.

Christopher D. Wickens, Lee, J., Liu, Y., & Becker, S. G. (2004). *An Introduction to Human Factors Engineering*. (L. Jewell, Ed.) (Internatio.). New Jersey: Pearson Education International.

CLIA. (2012). *Operational Safety Review Executive Summary*. *CLIA.*

Concise Oxford English Dictionary. (2001) (Tenth.). Oxford: Oxford University Press.

Department of Standards Malaysia. Personal Floatation Devices - Part 1:Lifejackets for Seagoing Ships - Safety Requirement (2008). Malaysia.

Dokkum, K. van. (2003). Ship Knowledge. Enkhuizen: DOKMAR.

Doll, T., Pfauth, M., Gleason, J., Cohen, S., Stiehl, C., Giuntini, R., & Hayes, B. (1978a). *Personal Flotation Device Research - Phase II Volume 1* (Vol. 1). West Huntsville.

Doll, T., Pfauth, M., Gleason, J., Cohen, S., Stiehl, C., Giuntini, R., & Hayes, B. (1978b). *Personal Flotation Devices Research - Phase II Volume 2* (Vol. 2). West Huntsville.

Doll, T., Pfauth, M., Gleason, J., Cohen, S., Stiehl, C., Giuntini, R., & Hayes, B. (1978c). *Personal Flotation Devices Research - Phase II Volume 3*.

Ergonomic Group Eastman Kodak Company. (1986). *Ergonomic design for people at work* (Vol. 1.). New York: Van Nostrand Reinhold.

FAA. (1996). *Criminal Act Against Civil Aviation*. Office of Civil Aviation Security, Federal Aviation Administration.

Frost, J. (2014). Regression Analysis: How to Interpret S, the Standard Error of the Regression. Retrieved May 26, 2014, from http://blog.minitab.com/blog/adventures-in-statistics/regression-analysis-how-to-interpret-s-the-standard-error-of-the-regression

Funkhouser, G. E., & Fairlie, G. W. (1991). *Donning Times and Flotation Characteristics of Infant Life Preservers: Four*.

Gabb, J. E., Davidson, A., & Ferres, H. M. (1965). Studies of the Principles of Floatation by Life Jackets. *Proceedings of the Royal Society of Medicine*, *58*(February), 97–98.

Genaidy, A., Karwowski, W., Shell, R., Khalil, A., Tuncel, S., Cronin, S., & Salem, S. (2005). Work compatibility : An integrated diagnostic tool for evaluating musculoskeletal responses to work and stress outcomes. *International Journal of Industrial Ergonomics*, *35*, 1109–1131. doi:10.1016/j.ergon.2005.06.003

Groff, P., & Ghadiali, J. (2003). *Will it Float ? Mandatory PFD Wear Legislation in*

Canada. Toronto.

Hamby, D. M. (1994). A review of techniques for parameter sensitivity analysis of environmental models. *Environmental Monitoring and Assesment*, *32*, 135–154.

Harkey, D. L., Reinfurt, D. W., & Knuiman, M. (1998). Development of the Bicycle Compatibility Index. *Journal of the Transportation Research Board*, *1636*(98), 13–20.

Hart, C. J. (1988). *A Study of the Factors Influencing the Rough Water Effectiveness of Personal Flotation Devices*.

Herrmann, R. (1989). Protection clothes and their influence on the function of life-jackets. *Bulletin Institute of Maritime and Tropical Medicine in Gdynia*, *40*(3-4), 225–232.

Hohenegger, J., Bufardi, A., & Xirouchakis, P. (2007). A new concept of compatibility structure in new product development. *Advanced Engineering Informatics*, *21*(1), 101–116. doi:10.1016/j.aei.2006.09.005

IMO. (1994). *MSC/Circular.668 - Alternative Arrangements For Halon Fire-extinguishing Systems In Machinery Spaces And Pump-rooms*. London: IMO.

IMO. (1995). MSC/Circular.681 - Guidelines for Passenger Safety Instruction on Ro-Ro Passenger Ships. London, United Kingdom: IMO.

IMO. (1997). *Resolution MEPC.76(40)*. *IMO*. London: IMO.

IMO. (1998). *Resolution MSC.81(70) - Revised Recommendation on Testing of Life-Saving Appliances*. London: IMO.

IMO. (2001). *IMO Resolution A.918(22) - Standard Marine Communication Phrases*. London: IMO.

IMO. (2005). *Resolution MSC.200(80) - Adoption of Amendments to the Revised Recommendation on Testing of Life-Saving Appliances*. London: IMO.

IMO. (2007). MSC.1/Circ.1238 - Guidelines for Evacuation Analysis for New and Existing Passenger Ships. London, United Kingdom: IMO.

IMO. (2009a). *International Code On Intact Stability, 2008* (3rd ed.). London: IMO.

IMO. (2009b). *SOLAS Consolidated Edition 2009*. London: IMO.

IMO. (2010). *Life-saving Appliances: Including LSA Code* (2nd ed.). London: IMO.

Indran, J. (1995a, November). 16.5m Fast Launch from Cheoy Lee. *Work Boat World*, 20.

Indran, J. (1995b, November). Austal reachses new milestone with 25 deliveries to China. *Work Boat World*, 28.

Indran, J. (1999, January). Xunlong 2. *Work Boat World*, 34.

ISO. (2005). ISO 12402-1:2005 Personal floatation devices - Part 1 Lifejackets for seagoing ships - Safety requirements. Geneva: ISO.

ISO. (2011). ISO 3864-1:2011 Graphical symbols - Safety colours and safety signs - Part 1: Design principles for safety signs and safety markings. Geneva: ISO.

Jeffs, A. (1999a, September). SuperCat 20. *Work Boat World*, 22.

Jeffs, A. (1999b, September). “Supercat 20” Local product for Philippines ferry operator. *Work Boat World*, 22.

Johnson, H. (2005). *Mastering Digital Printing*. Thomson Course Technology.

Krejcie, R. V, & Morgan, D. W. (1970). ACTIVITIES. *Educational and Psychological Measurement*, *38*, 607–610.

Lockhart, T. L., Jamieson, C. P., Steinman, A. M., & Giesbrecht, G. G. (2005). Life Jacket Design Affects Dorsal Head and Chest Exposure , Core Cooling , and Cognition in 10 ° C Water. *Aviation, Space, and Environmental Medicine*, *76*(10), 954 – 962.

Lois, P., Wang, J., Wall, A., & Ruxton, T. (2004). Formal safety assessment of cruise ships. *Tourism Management*, *25*(2004), 93–109. doi:10.1016/S0261-5177(03)00066-9

Longmuir, B. (1999, July). Yankee Freedom II. *Work Boat World*, 10.

Lu, C. S., & Tseng, P. H. (2012). Identifying crucial safety assessment criteria for passenger ferry services. *Safety Science*, *50*(7), 1462–1471. doi:10.1016/j.ssci.2012.01.019

Lu, C. S., & Yang, C. S. (2011). Safety climate and safety behavior in the passenger ferry context. *Accident Analysis and Prevention*, *43*(1), 329–341. doi:10.1016/j.aap.2010.09.001

Macdonald, C. V., Brooks, C. J., & Kozey, J. W. (2011). The Influence of Familiarity on Life Jacket Donning Performance : Implications for Participant Selection. *International Journal of Occupational Safety and Ergonomics*, *17*(1), 15–23.

MacDonald, C. V, Brooks, C. J., Kozey, J. W., & Habib, A. (2011). An ergonomic evaluation of infant life jackets: Donning time & donning accuracy. *Applied Ergonomics*, *42*(2), 314–20. doi:10.1016/j.apergo.2010.08.002

Macesker, B., & Gareau, G. (1997). *New Tools for Coast Guard Research of the Rough Water Performance of Personal Floatation Devices (PFDs)*.

Macesker, B., & White, R. P. (1992). *Coast Guard Approach to Develop Improved Personal Floatation Devices*.

Macintosh, R. R., & Pask, E. A. (1957). The Testing of Life-Jackets. *British Journal of Industrial Medical*, 168–176.

MAIB. (2001). *Report of the investigation of the capsized of a school boat on Fountain Lake, Portmouth with the loss of one life on 16 September 1999*. Southampton.

MAIB. (2008). *Report on the investigation of the capsize of Army Cadet Force Rigid Raiding Craft in Loch Carnan, South Uist, Western Isles of Scotland*. Southampton.

Maritime Safety Queensland. (2012). Frequently asked questions – compulsory wearing of life jackets. Retrieved November 3, 2013, from http://www.msq.qld.gov.au/

MCA. (1999). MGN 76 (M) - Lifejackets carried on Passenger Ships. Southampton, United Kingdom: Crown.

MCA, & AINA. Inland Waters Small Passenger Boat Code (2007). United Kingdom.

NSW Government Transport Maritime. (2013). Lifejacket - Wear it ! Retrieved November 3, 2013, from http://www.maritime.nsw.gov.au/index.html

NTSB. (2002). *Fire On Board the Small Passenger Vessel Port Imperial Manhattan , Hudson River New York City , New York*. Washington.

Ohtagaki, I. (2010, July). Passenger Vessels “Suisei.” *Work Boat World*, 32.

Pardoe, I. (2012). *Applied Regression Modeling* (2nd Editio.). Hoboken. Retrieved from John Wiley & Sons Inc

Pask, E. A. (1961). The Design of Life-Jackets. *British Medical Journal*, 1140–1142.

Pask, E. A., & Christie, P. D. (1962). Design of Life-Jackets. *British Medical Journal*, (Aug, 4), 333–335.

Piaw, C. Y. (2009). *Statistik Penyelidikan Lanjutan II*. Kuala Lumpur: McGraw-Hill.

Piaw, C. Y. (2011). *Kaedah Penyelidikan Buku 1* (2nd ed.). Kuala Lumpur: McGraw-Hill.

Piaw, C. Y. (2012). *Asas Statistik Penyelidikan Buku 2* (2nd ed.). Kuala Lumpur: McGraw-Hill.

Roberts, J. (1999, January). MV Mistral. *Work Boat World*, 21.

Roberts, N. H., & Vesely, W. E. (1987). *Fault Tree Handbook*. Government Printing Office.

Singhal, J., & Singhal, K. (1996). The number of feasible designs in a compatibility matrix. *European Journal of Operational Research*, *94*(1), 186–193. doi:10.1016/0377-2217(95)00197-2

Singhal, K. (1978). Integrating production decisions. *International Journal of Production Research*, *16*, 383–393.

Svein Kristiansen. (2005). *Maritime Transportation: Safety Management and Risk Analysis*. New York: Butterworth-Heinemann.

Tawfik, S. L. (2006, January). “Jelfar” and "Jelfar 2’ are economical 18 metre medium-speed ferries for the UAE. *Work Boat World*.

Taylor, M. (2009). What is sensitivity analysis ? *Health economics*. Retrieved from http://www.whatisseries.co.uk/

Transport Canada. (2002). Passenger Safety Briefings. *Ship Safety Bulletin*. Retrieved July 5, 2013, from http://wwwapps.tc.gc.ca/Saf-Sec-Sur/4/bulletins/

Transportation Safety Board of Canada. (1994). *A Safety Study of Survivability in Seaplane Accidents*. Minister of Supply and Services Canada.

Transportation Safety Board of Canada. (2011). *Loss of Control - Collision with Water*. Minister of Public Works and Government Services Canada.

Tzannatos, E. S. (2005). Technical reliability of the Greek coastal passenger fleet. *Marine Policy*, *29*(1), 85–92. doi:10.1016/j.marpol.2004.04.001

USCG. (2012). Small Passenger Vessel Information Guide. Retrieved July 14, 2013, from http://www.uscg.mil/d8/sectumr/Prevention

Viking Life-Saving Equipment A/S. (2013). The VIKING Maritime Safety Catalogue. Retrieved from http://www.viking-life.com/viking.nsf/public/downloads-downloadbrochures.html

Virk, A., & Pikora, T. J. (2011). Developing a tool to measure safe recreational boating practice. *Accident Analysis and Prevention*, *43*(1), 447–450. doi:10.1016/j.aap.2010.09.016

Wallis, J. (1999, September). Sea Speed 1. *Work Boat World*, 29–30.

Wallis, J. (2006, January). Patea Explorer. *Work Boat World*, 33.

Wang, G., Spencer, J., & Chen, Y. (2002). Assessment of a ship’s performance in accidents. *Marine Structures*, *15*(4-5), 313–333. doi:10.1016/S0951-8339(02)00017-5

Wang, J. (2002). Offshore safety case approach and formal safety assessment of ships. *Journal of Safety Research*, *33*(1), 81–115. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11979639

Wang, J., & Foinikis, P. (2001). Formal safety assessment of containerships. *Marine Policy*, *25*(2), 143–157. doi:10.1016/S0308-597X(01)00005-7

Wickens, C. D., Lee, J. D., Liu, Y., Becker, S. E. G., & Wickens, C. D. (2004). *An*

Introduction to Human Factor Engineering. (L. Jewell, Ed.) (2nd ed.). New Jersey: Pearson Prentice Hall.